DETERMINATION OF REFRACTIVE INDEX AND THICKNESS OF TIO2 NANOPARTICLE-POLYMER COMPOSITE THIN FILM COATED ON A SPUTTERED GOLD LAYER BY BROADBAND SPECTRAL SURFACE PLASMON RESONANCE SPECTROSCOPY

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Mesoporous thin films and composite layers containing either nanoparticles or nanotubes or nanowires are of great current interest because of their unique physical and chemical properties and potential applications.[1,2] Determination of refractive index and thickness of such nanomaterial films is necessary for many kinds of applications. To do these, commercial ellipsometers are used [1,2]. Such equipments are expensive and therefore not easily available in many laboratories. Here we introduce an inexpensive and simple technique, i. e., spectral surface plasmon resonance (SPR) spectroscopy, for determination of refractive index and thickness of nanomaterial layers

SPR is a well-known powerful sensing technique for detection of chemical and biological molecules [3,4]. SPR is also an effective tool for determination of refractive index and thickness of various thin films coated on the metal surfaces [5]. Popular SPR sensors operate at a single wavelength with an angular sensitivity. Different from these, a broadband, time-resolved spectral SPR sensor has been developed most recently in our group by using a polychromatic light source, a charge-coupled device detector and a 50-nm-thick gold layer sputtered on a slide glass substrate (see Fig. 1a). After covering the gold layers with the TiO_2 nanoparticle-polymer composite thin films fabricated from the ethanolic solution of polymer-stabilized TiO_2 colloids, we investigated the SPR absorption spectra of the resulting structure with either air or water in the flow cell. As shown in Fig. 1b, with water as the reference and air as the sample, the SPR peaks with air and the SPR dips with water were simultaneously observed, and these peak and dip positions are dependent on the incident angle. Note that without covering the gold layer by the TiO_2 nanoparticle-polymer composite thin film, the SPR absorption spectrum at a given incident angle consists of only a single peak (or dip). Fig. 2a and 2b show that the spectral SPR sensor is sensitive to refractive index of the aqueous sucrose solution, with both the resonant wavelength and effective refractive index being a linear function of the solution index of refraction.

By fitting the resonant wavelengths measured in Fig. 1b with numerical calculations, we determined that thickness and refractive index of the TiO_2 nanoparticle-polymer composite layer are 67.7 nm and 1.53 at λ = 786 nm. We also investigated the thickness of the composite film by atomic force microscopy (AFM). As shown in Fig. 3, the composite thin film is rather coarse relative to the sputtered gold layer due to the presence of TiO_2 nanoparticles. The height from the gold layer surface to that of the composite film is ~ 64 nm. The film thickness derived from the SPR measurements is very close to that measured by AFM, thereby accurate. The findings indicate that spectral SPR spectroscopy is applicable not only to chemical sensings but also to determination of thickness and refractive index of nanomaterial layers.

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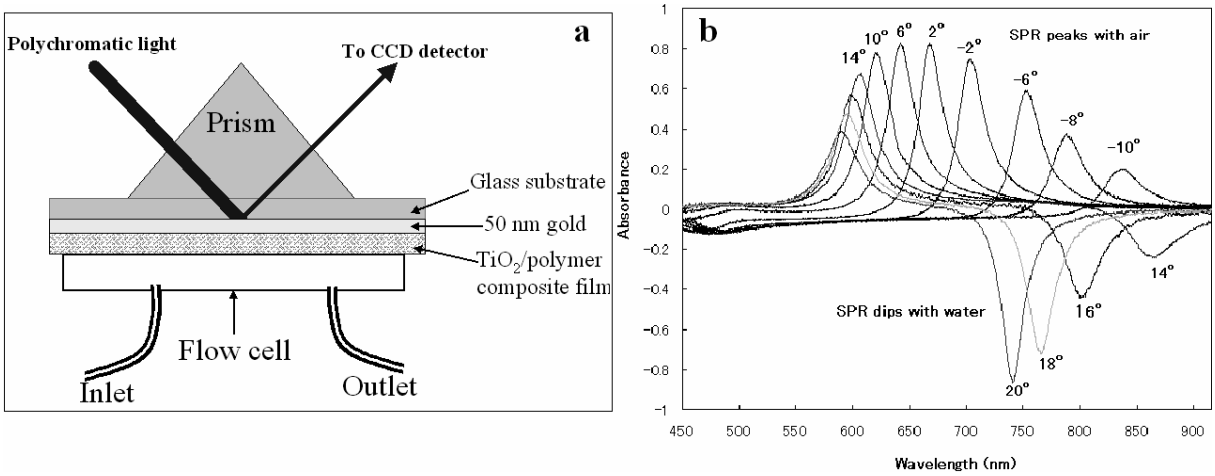

Fig. 1. (a) structure of a spectral SPR sensor coated with a TiO_2 nanoparticle-polymer composite thin film; (b) SPR absorption spectra at different incident angles

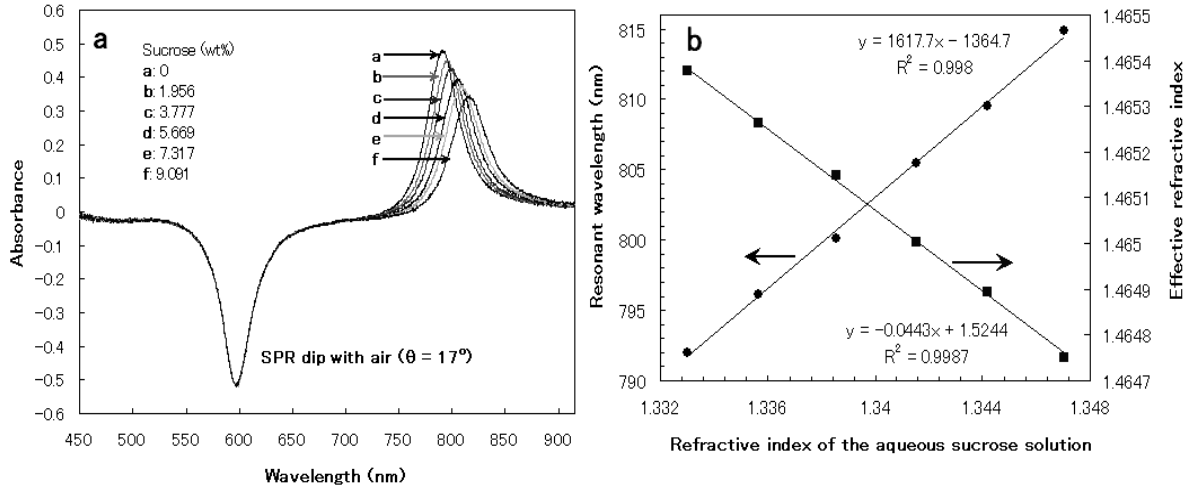

Fig. 2. (a) SPR absorption spectra measured with aqueous sucrose solutions in the cell; (b) dependences of resonant wavelength and effective refractive index on refractive index of the sucrose solution

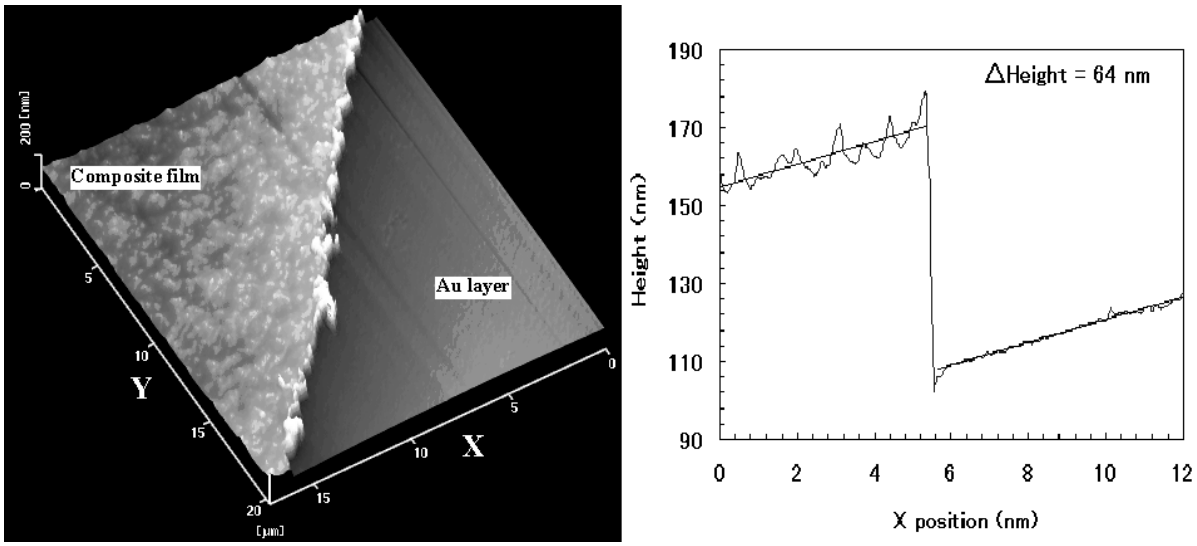

Fig. 3 Height profile of the TiO_2 nanoparticle-polymer composite thin film measured by atomic force microscopy.